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NOISE REDUCTION EFFORTS FOR SPECIAL OPERATIONS C-130 AIRCRAFT USING ACTIVE SYNCHROPHASER CONTROL

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BACKGROUND

Aircraft noise often inhibits mission effectiveness. As a result, flight crews, ground maintenance personnel, and passengers suffer degraded voice communication, impaired performance, increased fatigue, and hearing loss. The magnitude of these effects is dependent on both the exposure time and level of the noise. In an effort to reduce the level of noise both inside and outside of the aircraft, techniques have been developed that attempt to quiet the environment. The simplest approach uses passive noise reduction methods, including installing acoustic insulation and exhaust modifications, but these only provide limited success. A more complicated approach uses an active noise cancellation system, which offers improved performance that can augment passive methods to significantly reduce both internal and external aircraft noise.

ACTIVE NOISE CANCELLATION

Active noise cancellation (ANC) achieves noise reduction by creating an anti-noise, which is an equal and opposite acoustic wave that cancels the unwanted noise. This type of cancellation works well in smaller volumes, like headset ear cups, where the calculated acoustic canceling wave can easily drive tiny speakers located in the head set ear cup. For larger volumes or environments, arrays of loudspeakers are needed, but are often ineffective due to their size and weight. Since the primary noise on multi-engine turboprop aircraft, such as the C-130, originates from the engine-propeller system, the noise from one engine-propeller can be *tuned* to provide a canceling acoustic wave to reduce the noise generated from another engine-propeller operating on the same aircraft.

Because the levels of noise generated from each engine-propeller combination are similar under normal operating conditions, a means to adjust the propeller phasing to create a noise canceling effect is needed. For multi-engine propeller-driven aircraft, engine-propeller phase control is accomplished using an electromechanical device called a synchrophaser. Most turboprop aircraft in the Department of Defense (DoD) inventory incorporate synchrophasers that have fixed engine-propeller phase angle relationships that are factory set. Unfortunately, these pre-determined phase angles are not acoustically optimized for maximum noise reduction during all flight conditions.

ACTIVE SYNCHROPHASER SYSTEM

Thus, to optimally control the phase angle relationships among the four engine propellers, a controllable or active synchrophaser system is needed. One such

system was demonstrated on a NASA Lewis Research Center OV-10A aircraft in 1992. This system was a manually tuned analog system and resulted in 10-15 dB of interior noise reduction, but provided no external noise reduction because propeller phase angles were not dynamically controlled by the system. The Air Force Research Laboratory (AFRL) funded a second-generation phase-locked-loop digital synchrophaser in 1994. That system was flight-tested on a NASA Lewis Research Center OV-10A in 1995. The system demonstrated 3-5 dB reduction in exterior noise levels and a 10-15 dB reduction in cockpit noise levels. In 1995 and 1996, Lockheed Martin Control Systems (LMCS) designed and flight-tested a digital active synchrophaser in a commercial Beech 1900C aircraft.

MEETING AFSOC NEEDS

Realizing the noise canceling potential of an active synchrophaser system, Air Force Special Operations Command (AFSOC) prepared a technology roadmap in 1997 that identified several aircraft noise interference deficiencies related to operation of their C-130 aircraft. In fact, one concern stated that the aircraft commander might lose control of the crew during high stress conditions or emergencies due to the aircraft noise. Thus, United States Special Operations Command (USSOCOM) successfully obtained funding from the Office of Special Technology (OST) to partner with AFRL in demonstrating a new active synchrophaser technology for noise cancellation in Special Operations C-130 aircraft. AFSOC's responsibility was to provide the C-130 aircraft, flight and ground crew, test range, and other flight-test support. AFRL's responsibility was to initiate and manage a contract with LMCS who was to design, fabricate, integrate, install, and demonstrate the new active synchrophaser system. In addition, AFRL was to collect acoustic data to show the amount of exterior noise reduction accomplished by the new system. The primary objective of the LMCS contract was to reduce the exterior noise signature of the aircraft and interior noise levels by using acoustic measurements to optimally adjust the four propeller phase angles to cancel noise generated by the engine-propeller system.

CURRENT PROJECT STATUS

The prototype active synchrophaser control has passed the preliminary and critical design reviews and was initially ground tested in March 1999. Due to the unavailability of an AFSOC C-130 aircraft, the 40 FTS at Duke Field, Florida provided their C-130, ground, and maintenance crews. Photo 1 shows the 46 OG Test Director, Captain Todd Efaw, and other personnel installing the test equipment rack in the crowded cargo bay of the C-130.

Photo 1. 46 OG Test Director Capt. Todd Efaw Installs an Equipment Rack Needed for the New Active Synchrophaser Checkout.

Photo 2 shows the rack of flight test instrumentation for the initial data

collection. If the system goes into full production, installation of the new active synchrophaser will be as simple as removing the old synchrophaser box and installing the new unit. As LMCS was performing ground testing, the AFRL Noise Measurement Team was collecting baseline acoustical data needed prior to flight-testing.

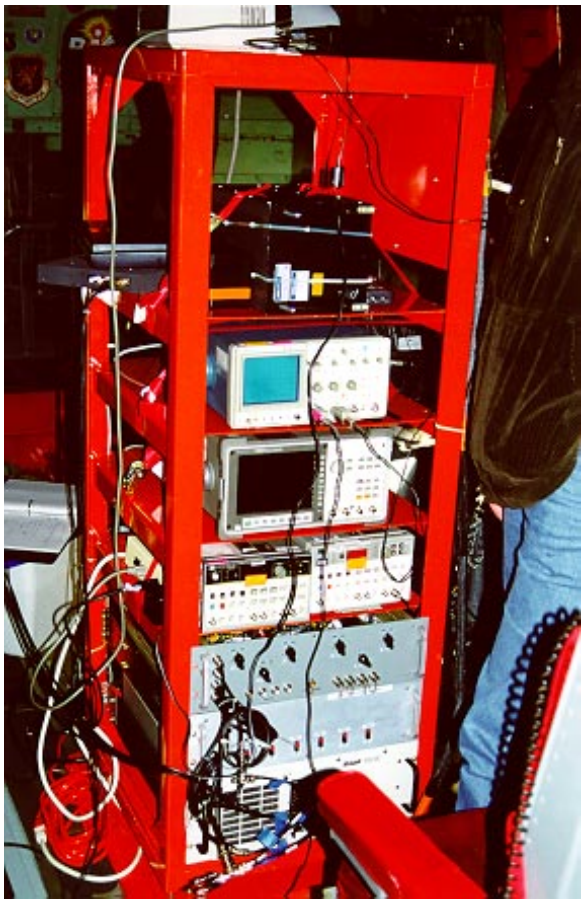

Photo 2. Prototype Active Synchrophaser and Other Test Equipment for System Checkout.

Photo 3 shows a member of the AFRL Noise Measurement Team performing system checkout of the acoustical data collection array installed around the aircraft. Recent analysis of the collected baseline acoustical data from the Duke Field test by AFRL research scientist Dr. Douglas Brungart indicates a potential for significant reduction in propeller noise from the new synchrophaser system. Final noise reduction capabilities will be measured during flight demonstrations.

Photo 3. Mr. Mike Patterson of AFRL's Noise Measurement Team Prepares to Record Engine-Propeller System Noise from the C-130.

IN CONCLUSION

Higher priority AFSOC mission requirements have temporarily delayed the final installation and flight-testing of the new active synchrophaser system. However, AFRL remains optimistic that flight-testing will resume later this year when reduced mission requirements will allow a C-130 aircraft to become available for this program. The benefits in relieving crew and passenger stress and fatigue, improvement in speech intelligibility, enhancement of mission effectiveness, and reduction in hearing loss of DoD personnel make demonstration of the new active synchrophaser system for noise cancellation imperative. It also remains a high priority with AFRL, who stands ready to meet the operational and safety needs of the Air Force.

Additional information on this project may be obtained by contacting Dr. Daryl Hammond at DSN 785-3671 Ext. 411 or via email at Daryl.Hammond@he.wpafb.af.mil.